M.Sc. Electrical Engineering and Information Technology (PO 2014)

Communication and Sensor Systems
Date: 01.10.2020

TECHNISCHE UNIVERSITÄT DARMSTADT

Department of Electrical Engineering and Information Technology

Module manual: M.Sc. Electrical Engineering and Information Technology (PO 2014)
Communication and Sensor Systems
Date: 01.10.2020

Department of Electrical Engineering and Information Technology
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	Course Nr.	Course name		
	18-zo-2060-ue	Digital Signal Processing		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Abdelhak Zoubir, M.Sc. Di Jin, M.Sc. Martin Gölz		Practice	1

Module name					
Microwave Engineering II					
Module Nr. 18-jk-2130	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1	**Content** Part 1 Passive microwave components: Calculation of the properties of simple passive components (microstrip line, filter, resonator, capacitor, inductance) for MMICs Part 2 Active microwave components: * Semiconductor material systems: properties, fabrication and requirements * Contacts to semiconductor devices: properties and characteristics * Charge carrier transport: characteristics and scattering processes * Field Effect Transistor (FET) and heterostructure transistors (HEMTs) Part 3 Active microwave circuits (main part): * Wave parameter and S-parameter * FET amplifier: operation, equivalent circuit, gain, matching circuit, stability and circuit implementation * Oscillator design * Mixer design Applications of these circuits range from communication systems such as cell phones to satellite transceivers as well as high-frequency souces up to Terahertz.
2	**Learning objectives / Learning Outcomes** Students will gain knowledge on the physics of microwave waveguides, resonators, microwave components (passive and active) as well as microwave circuits.
3	**Recommended prerequisite for participation** Desirable: Introduction to Electrodynamics, Microwave Engineering I
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iCE, MSc IST, Wi-ETiT
7	**Grade bonus compliant to §25 (2)**
8	**References** Script and slides will be handed out. Literature will be recommended in the lecture.

Courses

Course Nr.	Course name		
18-jk-2130-vl	Microwave Engineering II		
Instructor		**Type**	**SWS**
PD Dr.-Ing. Oktay Yilmazoglu, Prof. Dr. rer. nat. Sascha Preu		Lecture	3

	Course Nr.	Course name		
	18-jk-2130-ue	Microwave Engineering II		
	Instructor		**Type**	**SWS**
	PD Dr.-Ing. Oktay Yilmazoglu, Dr.-Ing. Shihab Al-Daffaie, Prof. Dr. rer. nat. Sascha Preu		Practice	1

Module name Information Theory II					
Module Nr. 18-pe-2010	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1	**Content** This lecture course is devoted to advances of network information theory. Outline: overview of Shannon capacity, outage and ergodic capacity, capacity of channels with state, capacity of Gaussian vector channels, capacity regions of multi-user channels, capacity regions of multiple-access and broadcast fading channels, interference channel, relay channel, multiuser bounds, multi-user diversity., wiretap channel, secrecy rate and physical layer security.
2	**Learning objectives / Learning Outcomes** Students will understand advanced concepts and strategies in networkinformation theory.
3	**Recommended prerequisite for participation** Knowledge of basic communication theory
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, BSc iST, MSc Wi-ETiT, MSc iCE, BSc/MSc CE
7	**Grade bonus compliant to §25 (2)**
8	**References** 1. Abbas El Gamal and Young-Han Kim, Network Information Theory, Cambrige, 2011. 2.. T.M. Cover and J.A. Thomas, Elements of Information Theory, Wiley Sons, 1991. 3.. D. Tse and P. Vishwanath, Fundamentals of Wireless Communications, Cambridge University Press, 2005.

Courses

Course Nr.	**Course name**		
18-pe-2010-vl	Information Theory II		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Lecture	3

Course Nr.	**Course name**		
18-pe-2010-ue	Information Theory II		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Practice	1

Module name Communication Technology II					
Module Nr. 18-kl-2010	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Anja Klein		

1	**Content** linear and nonlinear digital modulation schemes, optimum receivers for AWGN channels, error probability, channel capacity, channel models, channel estimation and data detection for multipath channels, multicarrier schemes, OFDM
2	**Learning objectives / Learning Outcomes** After completion of the lecture, students possess: • the ability of comparing, evaluating, classifying an analyzing linear and nonlinear modulation schemes by means of signal space representations; • the ability to understand, describe and analyze the influence of AWGN on the signal; • the ability to understand and derive optimum receivers in case of AWGN channels; • the ability to understand, describe and analyze the influence of multipath propagation on the signal; • the ability to describe the influence of a multipath channel mathematically (channel model) and estimate the multipath channel at the receiver; • the knowledge of equalizing the received signal in order to undo the influence of multipath propagation, as well as the ability to derive and design several equalizer structures; • the ability to analyze and evaluate the properties and application areas of multicarrier transmission systems, e.g. OFDM-systems; • the ability to design and evaluate the system parameters of multicarrier schemes for the application in realistic mobile radio scenarios;
3	**Recommended prerequisite for participation** Electrical Engineering I and II, Deterministische Signale und Systeme, Stochastische Signale und Systeme, Communication Technology I, Basics of Telecommunication, Mathematics I to IV
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETIT, MSc Wi-ETiT, MSc CE, MSc iCE, MSc iST, MSc MEC
7	**Grade bonus compliant to §25 (2)**
8	**References** will be announced in the lecture

Courses

	Course Nr. 18-kl-2010-vl	**Course name** Communication Technology II		
	Instructor Prof. Dr.-Ing. Anja Klein		**Type** Lecture	**SWS** 2

	Course Nr.	Course name		
	18-kl-2010-ue	Communication Technology II		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Anja Klein, M.Sc. Bernd Simon		Practice	1

Module name					
Laboratory Communication and Sensor Systems					
Module Nr. 18-jk-2050	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 105 h	**Duration** 1	**Cycle offered** WiSe
Language German and English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1	**Content** The student communications lab consist of 7 fundamental experiments out of the field of Communication Engineering: Mobile Radio Channel + Diversity (SW) Signal Detection and Parameter Estimation (Matlab) Digital Modulation (HW) Coding (SW) Parasitic Effects in Passive RF Devices (SW) RF FET Amplifier (HW) Polarization of Light (HW) Antennas: Fields and Impedance (HW)
2	**Learning objectives / Learning Outcomes** The students are guided to acquaint themselves with given topics. They learn to perform prepared experiments within a defined frame and minute, analyze and discuss the results. In this training the fundamentals of free scientific work are practiced.
3	**Recommended prerequisite for participation** Fundamentals of: • Communications • Microwave Engineering • Digital Signal Processing
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iCE, Wi-ETiT
7	**Grade bonus compliant to §25 (2)**
8	**References** A description of experiments is offered. It can be bought from Mr. Ziemann (S306/409) or being loaded from the WEB page.

Courses

Course Nr.	Course name		
18-jk-2050-pr	Laboratory Communication and Sensor Systems		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Rolf Jakoby, Prof. Dr.-Ing. Anja Klein, Dr.-Ing. Martin Schüßler		Internship	3

2 Optional Modules

2.1 KTS I: Lectures

Module name Adaptive Filters					
Module Nr. 18-zo-2010	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1	**Content** **Theory:** 1) Derivation of optimal filters for stochastic processes, e.g. Wiener filter or linear prediction filter based on suitable cost functions. 2) Elaboration of adaptive procedures, which allow to iteratively approach the optimal solution for non-stationary signals in non-stationary environments. Here, the adaptive procedures such as NLMS adaptation, affine projection, and the RLS algorithm are derived and extensively analysed. 3) Analysis of the adaptation behaviour and control procedures of adaptive filters based on the NLMS procedure. 4) Derivation and analysis of the Kalman filter as optimal filter for non-stationary input signals. 5) Procedures for the decomposition of signals into sub-bands for the realization of optimal filters in the frequency domain, e.g. noise reduction procedures. **Applications:** Parallel to the theory, practical applications are explained. As an example for the Weiner filter, the acoustic noise reduction procedures are explained. Acoustic echo cancellation and feedback cancellation are given as examples for adaptive filters. Furthermore beamforming approaches are introduced. It is planned to offer an excursion to Siemens Audiology Engineering Group in Erlangen. In the 4 to 5 exercises, some content of the lecture will be implemented in MATLAB which allows the students to get familiar with practical realizations of the theoretical procedures.
2	**Learning objectives / Learning Outcomes** During the lecture, basics of adaptive filters are taught. The necessary algorithms are derived, interpreted and applied to examples of speech, audio and video processing. Based on the content of the lecture you are able to apply adaptive filters to real practical applications. For the admission to the exam you give a talk about a topic in the domain of adaptive filters chosen by you. This will allow you to acquire the know-how to read and understand scientific literature, familiarize yourself with an unknown topic and present your knowledge, such as it will be certainly required from you in your professional life as an engineer.
3	**Recommended prerequisite for participation** Digital Signal Processing
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module**

	MSc ETiT
7	**Grade bonus compliant to §25 (2)**
8	**References** Slides of the lecture. Literature: • E. Hänsler, G. Schmidt: Acoustic Echo and Noise Control, Wiley, 2004 (Textbook of this course); • S. Haykin: Adaptive Filter Theory, Prentice Hall, 2002; • A. Sayed: Fundamentals of Adaptive Filtering, Wiley, 2004; • P. Vary, U. Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 1998 (in German)

Courses

Course Nr.	**Course name**		
18-zo-2010-vl	Adaptive Filters		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Henning Puder		Lecture	3

Course Nr.	**Course name**		
18-zo-2010-ue	Adaptive Filters		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Henning Puder		Practice	1

Module name Acoustics I					
Module Nr. 18-se-2010	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. (em.) Dr. Gerhard Sessler		

1	**Content** 1.Basic concepts of vibrations; impedance; electromechanical analogues, 2.sound field: wave equation; plane waves; sound absorption and dispersion; room absorption, 3.sound radiation: spherical, dipole, and cardioid source; linear arrays;circular piston membrane, 4.physiological and psychological acoustics: hearing organ; acoustic perception; speech production and-speech intelligibility, 5. electroacoustic transducers; reciprocity relations; electrostatic, piezoelectric, electrodynamic, and other transducers; directional microphones; microphone calibration, 6. acoustic measuring methods: measurements of fundamental acoustic quantities; acoustic testing chambers; vibration measurements, 7 analogical and digital sound recording: digital and analogical disc and magnetic tape methods; movie sound, 8. ultrasound and hypersound: generation and detection; applications
2	**Learning objectives / Learning Outcomes** After completion of the lecture, students possess: • the understanding of basic phenomena of generation, propagation, reception, storage and reproduction of sound; • the ability to analyze acoustic components and systems; • the ability to judge and design applications in the audio and ultrasonic frequency ranges.
3	**Recommended prerequisite for participation** Electrical Engineering I and II, Mathematics I to IV, Physics, Basics of Telecommunication
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT
7	**Grade bonus compliant to §25 (2)**
8	**References** H. Kuttruft, Akustik (Hilzel 2004); M. Zollner u. E. Zwicker, Elektroakustik, 3. Auflage (Springer, corrected reprint 1998); H. Fastl, E. Zwicker, Psychoacoustics (Springer 2005); J. Blauert, Communication Acoustics (Springer 2005); R.Lerch, G. Sessler u. D. Wolf, Technische Akustik (Springer 2009)

Courses

Course Nr.	**Course name**		
18-se-2010-vl	Acoustics I		
Instructor		**Type**	**SWS**
Prof. (em.) Dr. Gerhard Sessler, Prof. Dr. Mario Kupnik		Lecture	2

Module name Antennas and Adaptive Beamforming					
Module Nr. 18-jk-2020	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1	**Content** Overview of most important antenna parameters types as well as their applications. Fundamental theories: Fourier transform for far-field pattern calculations, antenna modeling techniques, antenna synthesis methods, image theory, determination of field regions of line sources, of the average radiated power density and power, directivity and gain. Antennas as key elements in power budgets of radio links, introducing the effective aperture of an antenna, deriving the relation between gain and effective aperture. Array antennas are a key hardware for beamforming and smart antenna systems: fundamentals of phased-scanning arrays, non-uniformly excited, equally spaced linear arrays, multi-dimensional planar arrays and mutual coupling effects. Wire antennas: still the most prevalent of all antenna forms, relatively simple in concept, easy to construct, very inexpensive. Antenna radiation fields and antenna parameters for different types of antennas are derived from Maxwell´s equations, applied for aperture antennas (horns, lenses or reflector antennas) and printed antennas (microstrip-patch and coplanar-slot antennas) Some basic numerical calculation methods: integral equation methods in the time and frequency domain, physical optics and uniform theory of diffraction are briefly summarized and compared for antennas and scattering problems. Smart antennas in communication and radar systems, with focus on beam steering and adaptive beamforming.
2	**Learning objectives / Learning Outcomes** Students will know basic antenna parameters: pattern, gain, directivity, half-power beamwidth, side- lobe-level, efficiency and input impedance to compare, assess and evaluate different antennas for various applications and operating frequencies. The antenna field regions, reactive near-field, near-field and far-field, can be differentiated and the far-field pattern of an antenna can be determined from given current distributions along the antenna by using Fourier transformation or integral solutions with distributed ideal dipoles as basic elements (antenna analysis). To assess in general physical requirements, constrains and limitations of antennas, students can use fundamental antenna theory: impedance matching techniques, antenna modeling and far-field pattern analysis, antenna synthesis, image theory and fundamental limits of electrically small antennas. After being incorporated into the different adaptive beamforming techniques, the array theory enables the student to design antenna systems that are assembled of a certain number of separate elements, feeding network, beamforming network etc. for phased-scanning or smart antennas in communications and sensing. Moreover, students are able to determine, analyze and evaluate the most important classes of antennas in wireless technology for many applications, operating frequencies, desired requirements or practical constrains: (1.) wire- dipole antennas, (2.) planar antennas (microstrip, dipole and slot antennas), (3.) aperture antennas (horn antennas, parabolic reflector antennas, lens antennas, Cassegrain and Gregorian double-reflector configurations), (4.) broadband and frequency-independent antennas (V antennas, biconical antennas, helical antennas, spiral and log-periodic antennas).
3	**Recommended prerequisite for participation** Fundamentals of Communications, Microwave Engineering 1
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** BSc ETiT, MSc ETiT, MSc iCE, Wi-ETiT
7	**Grade bonus compliant to §25 (2)**

8	**References** Jakoby, Skriptum Antennas and Adaptive Beamforming, wird am Beginn der Vorlesung verkauft und kann danach im FG-Sekretariat erworben werden

Courses

Course Nr.	Course name		
18-jk-2020-vl	Antennas and Adaptive Beamforming		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Rolf Jakoby, M.Sc. Matthias Nickel		Lecture	3
Course Nr.	**Course name**		
18-jk-2020-ue	Antennas and Adaptive Beamforming		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Rolf Jakoby, M.Sc. Matthias Nickel		Practice	1

Module name					
Convex Optimization in Signal Processing and Communications					
Module Nr. 18-pe-2020	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1	**Content** This graduate course introduces the basic theory of convex optimization and illustrates its use with many recent applications in communication systems and signal processing. Outline: Introduction, convex sets and convex functions, convex problems and classes of convex problems (LP, QP, SOCP, SDP, GP), Lagrange duality and KKT conditions, basics of numerical algorithms and interior point methods, optimization tools, convex inner and outer approximations for non convex problems, sparse optimization, distributed optimization, mixted integer linear and non-linear programming, applications.
2	**Learning objectives / Learning Outcomes** Students will learn the basic theory of convex optimization and its applications.
3	**Recommended prerequisite for participation** Knowledge in linear algebra and the basic concepts of signal processing and communications.
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Duration: 120 min, Standard Grading System) In general, the examination takes place in form of a written exam (duration: 120 minutes). If up to 13 students register, there examination can be an oral examination (duration: 20 min.). The type of examination will be announced in the beginning of the lecture or in semesters without a lecture within one working week after the end of the examination registration phase.
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT
7	**Grade bonus compliant to §25 (2)**
8	**References** 1. S. Boyd and L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004. (online Verfügbar: http://www.stanford.edu/~boyd/cvxbook/) 2. D. P. Bertsekas, Nonlinear Programming, Athena Scientific, Belmont, Massachusetts, 2nd Ed., 1999. 3. Daniel P. Palomar and Yonina C. Eldar, Convex Optimization in Signal Processing and Communications, Cambridge University Press, 2009.

Courses

Course Nr.	Course name		
18-pe-2020-vl	Convex Optimization in Signal Processing and Communications		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Lecture	2

Course Nr.	Course name		
18-pe-2020-ue	Convex Optimization in Signal Processing and Communications		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Practice	1

	Course Nr.	Course name		
	18-pe-2020-pr	Convex Optimization in Signal Processing and Communications Lab		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Marius Pesavento		Internship	1

Module name MIMO - Communication and Space-Time-Coding					
Module Nr. 18-pe-2030	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1	**Content** This lecture course introduces the principles of space-time and multiple-input multiple-output (MIMO) communications. Outline: Motivation and background; overview of space-time and MIMO communications; fading MIMO channel models, MIMO information theory, receive and transmit diversity; channel estimation, MIMO detectors, Alamouti space-time block code, orthogonal space-time block codes; linear dispersion codes; coherent and non-coherent decoders, differential space-time block coding; MIMO with limited feedback, Multiantenna- and multiuser diversity, BER performance analysis, MIMO in moden wireless communication networks, multicell and multiuser MIMO (coordinated multipoint).
2	**Learning objectives / Learning Outcomes** Students will understand modern MIMO communications and existing space-time coding techniques.
3	**Recommended prerequisite for participation** Knowledge of basic communication theory and basic information theory.
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT
7	**Grade bonus compliant to §25 (2)**
8	**References** 1. A.B.Gershman and N.D.Sidiropoulos, Editors, Space-Time Processing for MIMO Communications, Wiley and Sons, 2005. 2. E.G.Larsson and P.Stoica, Space-Time Block Coding for Wireless Communications, Cambridge University Press, 2003; 3. A.Paulraj, R.Nabar, and D.Gore, Introduction to Space-Time Wireless Communications, Cambridge University Press, 2003. 4. Lin Bai and Jinho Choi, Low Complexity MIMO detectors, Springer, 2012. 5. Howard Huang, Constantinos B. Papadias, and Sivarama Venkatesan, MIMO Communication for Cellular Networks, Springer, 2012.

Courses

Course Nr.	Course name	Instructor	Type	SWS
18-pe-2030-vl	MIMO - Communication and Space-Time-Coding	Prof. Dr.-Ing. Marius Pesavento	Lecture	2
18-pe-2030-ue	MIMO - Communication and Space-Time-Coding	Prof. Dr.-Ing. Marius Pesavento, M.Sc. Fabio Nikolay, M.Sc. Tianyi Liu	Practice	1

Module name					
Mobile Communications					
Module Nr. 18-kl-2020	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Anja Klein		

1 Content

The lecture covers aspects of mobile communication systems with particular focus on the physical layer.
Mobile radio systems, services, market, standardization
duplex and multiple access techniques, cellular concept
mobile radio channel, deterministic and stochastic description
modulation schemes
code division multiple access (CDMA)
orthogonal frequency division multiplexing (OFDM)
optimum and suboptimum receiver techniques
cellular radio capacity and spectrum efficiency
diversity methods
multiple input multiple output (MIMO) systems
power control and handover
architecture of mobile radio systems

2 Learning objectives / Learning Outcomes

After completion of the lecture, students possess

- a profound understanding of physical layer aspects ,e.g., transmission schemes, multiple access schemes of mobile communication systems, duplex schemes, multi carrier schemes, receiver techniques, multi antenna schemes
- a profound understanding of signal propagation in mobile radio systems (mobile radio channel)
- the ability to understand and solve problems of the field of the physical layer
- the ability to compare, analyse and evaluate different system concepts
- knowledge on modelling of the transmission properties of the mobile radio channel

3 Recommended prerequisite for participation

Electrical Engineering I and II, Deterministic Signals and Systems, Communication Technology I, Mathematics I to IV

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

MSc ETIT, MSc Wi-ETiT, MSc CE, MSc iCE, MSc iST, MSc MEC

7 Grade bonus compliant to §25 (2)

8 References

will be announced in the lecture

Courses

	Course Nr. 18-kl-2020-vl	**Course name** Mobile Communications		
	Instructor Prof. Dr.-Ing. Anja Klein		**Type** Lecture	**SWS** 3
	Course Nr. 18-kl-2020-ue	**Course name** Mobile Communications		
	Instructor Prof. Dr.-Ing. Anja Klein		**Type** Practice	**SWS** 1

Module name Digital Signal Processing Lab					
Module Nr. 18-zo-2030	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 135 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1	**Content** 1) Introduction to MATLAB 2) Discrete-Time Signals and Systems 3) Frequency-Domain Analysis using the DFT 4) Digital FIR Filter Design 5) IIR Filter Design using Analog Prototypes 6) Nonparametric Spectrum Estimation 7) Parametric Spectrum Estimation.
2	**Learning objectives / Learning Outcomes** The students are able to apply skills acquired in the course Digital Signal Processing. These include the design of digital FIR and IIR filters as well as non-parametric and parametric spectrum estimation. Students learn how MATLAB is used to apply theoretical concepts and to demonstrate signal processing techniques by using hands-on application examples.
3	**Recommended prerequisite for participation** Deterministic signals and systems theory
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Written Examination, Duration: 120 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iCE
7	**Grade bonus compliant to §25 (2)**
8	**References** Lab manual

Courses

	Course Nr. 18-zo-2030-pr	**Course name** Digital Signal Processing Lab		
	Instructor Prof. Dr.-Ing. Abdelhak Zoubir		**Type** Internship	**SWS** 3

Module name Radar Techniques					
Module Nr. 18-jk-2040	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1	**Content** First, there will be an introduction of different radar techniques, describing their concepts and principles, their applications and the operating frequency ranges. In a historical survey, the radar ranges and propagation effects will be dealt with. In the second part, various primary and secondary radar techniques will be investigated in detail, including specific techniques of radar signal processing and -analysis.
2	**Learning objectives / Learning Outcomes** Students will know about concepts and principles to detect objects as well as to determine the angular position and range of objects. They learn about the functional principles of various radar systems, including signal processing. They will understand the major physical propagation effects.
3	**Recommended prerequisite for participation** Fundamentals of Communications, Microwave Engineering I
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iCE, MSc Wi-ETiT
7	**Grade bonus compliant to §25 (2)**
8	**References** Slides, Latest Publications and Books

Courses

Course Nr.	Course name		
18-jk-2040-vl	Radar Techniques		
Instructor Dr.-Ing. Holger Maune		**Type** Lecture	**SWS** 2

Module name					
Speech and Audio Signal Processing					
Module Nr. 18-zo-2070	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1	**Content** Algorithms of speech and audio signal processing: Introduction to the models of speech and audio signals and basic methods of audio signal processing. Procedures of codebook based processing and audio coding. Beamforming for spatial filtering and noise reduction for spectral filtering. Cepstral filtering and fundamental frequency estimation. Mel-filterind cepstral coefficients (MFCCs) as basis for speaker detection and speech recognition. Classification methods based on GMM (Gaussian mixture models) and speech recognition with HMM (Hidden markov models). Introduction to the methods of music signal processing, e.g. Shazam-App or beat detection.
2	**Learning objectives / Learning Outcomes** Based on the lecture you acquire an advanced knowledge of digital audio signal processing mainly with the help of the analysis of speech signals. You learn about different basic and advanced methods of audio signal processing, to range from the theory to practical applications. You will acquire knowledge about algorithms such as they are applied in mobile telephones, hearing aids, hands-free telephones, and man-machine-interfaces (MMI). The exercise will be organized as a talk given by each student with one self-selected topic of speech and audio processing. This will allow you to acquire the know-how to read and understand scientific literature, familiarize with an unknown topic and present your knowledge, such as it will be certainly required from you in your professional life as an engineer.
3	**Recommended prerequisite for participation** Knowlegde about satistical signal processing is required (lecture „Digital Signal Processing“). Desired – but not mandatory – is knowledge about adaptive filters.
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Duration: 20 min, Standard Grading System) Seminar presentation: Scientific talk about a topic in the field of “Speech and Audio Signal Processing”, single (duration 10-15 min) or in groups of two students (15-20 min)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iCE
7	**Grade bonus compliant to §25 (2)**
8	**References** Slides (for further details see homepage of the lecture)

Courses

Course Nr.	Course name	Instructor	Type	SWS
18-zo-2070-vl	Speech and Audio Signal Processing	Prof. Dr.-Ing. Henning Puder	Lecture	2
18-zo-2070-ue	Speech and Audio Signal Processing	Prof. Dr.-Ing. Henning Puder	Practice	1

	Course Nr.	Course name		
	18-zo-2070-se			
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Henning Puder		Seminar	1

Module name Computational Methods for Systems and Synthetic Biology					
Module Nr. 18-kp-2080	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr. techn. Heinz Köppl		

1	**Content** The course covers mathematical methods used in the area of systems and synthetic biology. On the one hand it deals with practical modeling of molecular processes but also with theoretical investigations that reveal general properties of those processes. The course follows a microscopic approach and introduces those processes using probabilistic methods. For that, necessary prerequists are recapitulated, such as definition of Markov processes in different spaces and their properties. With this background, the dynamics of stochastic reaction kinetics in terms of population models is investigated. Limiting cases are introduced, such as the diffusion approximation or the deterministic approximation (fluid approximations) of those systems. Often methods from statistical physics are applied. Numerical methods for solving the corresponding Fokker-Planck and Master equations are discussed. For the limiting case of a deterministic approximation, traditional methods for the stability analysis of nonlinear differential equations are introduced and methods are discussed that just rely on the topology of the reaction network to determine stability properties. In this context, a derivation of the moment dynamics and approximation methods based on moment closure are given. Connections to queueing theory models are shown. Furthermore, the question is addressed of how the introduced dynamical models are calibrated to data from molecular biology. For that, general methods of statistical inference from statistics and of machine learning from computer science are discussed and specialized algorithms for the considered system class are presented. Additionally, a short introduction to the theory of nonlinear optimal filtering is given and special cases such as hidden Markov models are discussed. Beyond reaction kinetics, the course provides a basic introduction to the modeling and numerical methods used in molecular dynamics. Newtonian multi-body simulations and classical potentials and their use in molecular dynamics are discussed. Most of the topics in this course are introduced through practical examples from applied modeling in the domain of systems biology. The applicability of the respective methods in synthetic biology is highlighted.
2	**Learning objectives / Learning Outcomes** Students that successfully passed that course should be able to perform practical modeling of molecular processes and to determine dynamical properties of model using mathematical methods. It relies on the understanding of the following topics: • Mathematical abstraction of molecular mechanisms • General properties of stochastic processes • Approximation methods for Markovian population models • Stability analysis of nonlinear differential equations • Numerical methods for solving/simulating stochastic systemsSystem identification/machine learning for stochastic systems
3	**Recommended prerequisite for participation** Basic knowledge of programming, Matlab.
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iST, MSc Wi-ETiT, MSc MEC

7	**Grade bonus compliant to §25 (2)**			
8	**References** http://www.bcs.tu-darmstadt.de/			
Courses				
	Course Nr. 18-kp-2080-vl	**Course name** Computational Methods for Systems and Synthetic Biology		
	Instructor Prof. Dr. techn. Heinz Köppl		**Type** Lecture	**SWS** 2
	Course Nr. 18-kp-2080-ue	**Course name** Computational Methods for Systems and Synthetic Biology		
	Instructor Prof. Dr. techn. Heinz Köppl		**Type** Practice	**SWS** 1

Module name Sensor Array Processing and Adaptive Beamforming					
Module Nr. 18-pe-2060	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1 Content

This lecture course introduces the principles of modern sensor array processing and adaptive beamforming.
Outline: Motivation and background; applications, narrowband and wideband signal model
Direction-of-arrival estimation (DoA):
traditional methods based on beamforming, super resolution methods, Maximum-Likelihood methods, Subspace based methods, MUSIC, ESPRIT, MODE, root-MUSIC, multidimensional source localization, beamspace processing, array interpolation, partly calibrated arrays, wideband DOA estimation, spatial smoothing, forward-backward averaging, redundancy averaging, correlated sources, minimum redundancy arrays, compressed sensing and sparse reconstruction based DoA estimation, performance bounds
Adaptive beamforming:
Point-source model, covariance model, Wiener-Hopf equation, Minimum Variance Distortionless Response (MVDR) beamformer, Capon Beamformer, sample matrix inversion, signal self-nulling effect, robust adaptive beamforming, Hung-Turner projection beamformer, Generalized Sidelobe canceller beamformer, Eigenspace-based beamformer, non-stationary environments, modern convex optimization based beamforming, worst-case based beamforming, multiuser beamforming.

2 Learning objectives / Learning Outcomes

Students will standard and modern sensor array processing techniques for source localization and transmit/receive beamforming

3 Recommended prerequisite for participation

Knowledge in linear algebra.

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Optional, Weighting: 100 %)

6 Usability of this module

BSc / MSc etit, BSc / MSc WI-etit, MSc MEC, MSc iST, MSc iCE

7 Grade bonus compliant to §25 (2)

8 References

- Academic Press Library in Signal Processing: Volume 3 Array and Statistical Signal Processing Edited by Rama Chellappa and Sergios Theodoridis, Section 2, Edited by Mats Viberg, Pages 457-967 (2014)
  - Chapter 12 - Adaptive and Robust Beamforming, Sergiy A. Vorobyov, Pages 503-552
  - Chapter 14 - DOA Estimation Methods and Algorithms, Pei-Jung Chung, Mats Viberg, Jia Yu, Pages 599-650
  - Chapter 15 - Subspace Methods and Exploitation of Special Array Structures, Martin Haardt, Marius Pesavento, Florian Roemer, Mohammed Nabil El Korso, Pages 651-717
- Spectral Analysis of Signals, Petre Stoica, Randolph Moses, Prentice Hall, April 2005Optimum Array Processing: Part IV of Detection, Estimation, and Modulation Theory, Harry L. Van Trees, Wiley Online, 2002.

Courses

<table>
<tr><td rowspan="2"></td><td>Course Nr.
18-pe-2060-vl</td><td colspan="3">Course name
Sensor Array Processing and Adaptive Beamforming</td></tr>
<tr><td colspan="2">Instructor
Prof. Dr.-Ing. Marius Pesavento</td><td>Type
Lecture</td><td>SWS
2</td></tr>
<tr><td rowspan="2"></td><td>Course Nr.
18-pe-2060-ue</td><td colspan="3">Course name
Sensor Array Processing and Adaptive Beamforming</td></tr>
<tr><td colspan="2">Instructor
Prof. Dr.-Ing. Marius Pesavento</td><td>Type
Practice</td><td>SWS
1</td></tr>
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Module name Microwave Measurement Technologies					
Module Nr. 18-jk-2090	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1	**Content** Introduction to microwave measurement technoloies, high frequency components and their poperties: rf power measurement, spectrum analysis, vertor network analysis (s-parameter, x-parameter, calibration techniques), on-wafer measurements, load/source-pull, material characterization
2	**Learning objectives / Learning Outcomes** By this module, Students will be enabled to undetstand the basic principles of microwave measuement technologies. They are able to use them in measurement applications. The following objectives are linked to the lecture: • The students understand the basic features of the power measurements and the effects of a mismatch or pulsed signals and can independently carry out and interpret measurements. • The students understand the basics of spectrum analysis and can carry out and interpret measurements independently. • The students understand the basics of s-parameter measurements and calibration of network analyzers and can carry out and interpret measurements independently • Students are familiar with various methods for material characterization
3	**Recommended prerequisite for participation** Recommended: Grundlagen der Nachrichtentechnik, Hochfrequenztechnik I
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Duration: 45 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc etit, MSc WI-etit, MSc iCE, MSc iST
7	**Grade bonus compliant to §25 (2)**
8	**References**

Courses

Course Nr.	**Course name**	**Instructor**	**Type**	**SWS**
18-jk-2090-vl	Microwave Measurement Technologies	Dr.-Ing. Holger Maune	Lecture	2
18-jk-2090-ue	Microwave Measurement Technologies	Dr.-Ing. Holger Maune	Practice	1

	Course Nr.	Course name		
	18-jk-2090-pr	Microwave Measurement Technologies Lab		
	Instructor		**Type**	**SWS**
	Dr.-Ing. Holger Maune		Internship	1

Module name Machine Learning & Energy					
Module Nr. 18-st-2020	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr. rer. nat. Florian Steinke		

1	**Content** The analysis and interpretation of data becomes ever more important, also for engineers. Digitalization and Smart Grids are terms to describe a host of novel data-based services in the field of generation, distribution, consumption and marketing of (renewable) energy. The lecture presents the recent developments and their underlying principles of machine learning technology. For a start we will describe the different problem settings of machine learning in a structured way (classification, regression, clustering, dimensionality reductions, time series models, ...) and present for each setting relevant applications from the energy sector (prediction of renewable energy or consumption in multimodal energy systems, fault detection and prediction, data visualization, robust investments decisions, customer analysis, probabilistic load flow, ...). Thereafter we will briefly review necessary tools from optimization and probability theory, as well as introduce probabilistic graphical models. With these tools we will then study for each problem setting one or more machine learning algorithms in detail, together with use cases from the energy domain. Classic algorithms will be developed (e.g. linear regression, k-means, principal component analysis, ...) as well as modern ones (e.g. SVMs, Deep Learning, Collaborative filtering, ...). Practical exercise with Matlab will deepen the understanding and support student's active knowledge.
2	**Learning objectives / Learning Outcomes** Students understand important machine learning problem settings and some key algorithms for each task. They know common applications thereof in the energy domain. Moreover, the students are able to apply and adapt those methods independently to new applications (not only from the energy domain).
3	**Recommended prerequisite for participation** • Good knowledge of linear algebra and the foundations of numerical optimization (e.g. from the course 18-st-2010 Energieanagement & Optimierung) • Using Matlab for programming the practical examples should pose no difficulty. A block tutorial on the use of Matlab is offered as 18-st-2030 Matlab Grundkurs.
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc etit, MSc iST, MSc Wi-etit, MSc CE
7	**Grade bonus compliant to §25 (2)** Notenverbesserungen bis zu 0,4 nach APB §25(2) durch Bonus für regelmäßig besuchte Übungs-/Praktikumstermine und mindestens einmaliges Vorrechnen in den Übungen
8	**References** • A Géron: Hands on Machine Learning with scikit-learn and Tensorflow, 2017 • Friedman, Hastie, Tibshirani: The elements of statistical learning, 2001 • Koller, Friedmann: Graphical Models, 2009

Courses

	Course Nr. 18-st-2020-vl	**Course name** Machine Learning & Energy		
	Instructor Prof. Dr. rer. nat. Florian Steinke, M.Sc. Tim Christian Janke		**Type** Lecture	**SWS** 2
	Course Nr. 18-st-2020-ue	**Course name** Machine Learning & Energy		
	Instructor Prof. Dr. rer. nat. Florian Steinke		**Type** Practice	**SWS** 1
	Course Nr. 18-st-2020-pr	**Course name** Machine Learning & Energy Lab		
	Instructor Prof. Dr. rer. nat. Florian Steinke, M.Sc. Tim Christian Janke		**Type** Internship	**SWS** 1

Module name					
Machine Learning in Information and Communication Technology (ICT)					
Module Nr. 18-kp-2110	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Anja Klein		

1	**Content** The module provides an introduction to the emerging field of machine learning from an engineering perspective. Important models and learning methods are presented and exemplified through problems from information and communication technology. • Fundamentals of probability theory and multivariate statistics • Taxonomy of machine learning problems and models (supervised, unsupervised, generative, discriminative) • Regression and classification: theory, methods and ICT applications • Dimensionality reduction, clustering and big data analytics: methods and application in communications and signal processing • Probabilistic graphical models: categories, inference and parameter estimation • Fundamentals of Bayesian inference, Monte Carlo methods, Bayesian non-parametrics • Fundamentals of convex optimization: Solution methods and application in communications • Approximate algorithms for scalable Bayesian inference; application in signal processing and information theory (e.g. decoding of LDPC codes) • Hidden Markov models (HMM): Theory, Algorithms and ICT applications (e.g. Viterbi decoding of convolutional codes) • High-dimensional statistics (“large p small n” setting), learning dependency structure in high-dimensional data, learning causality relations from observational data. • Sparse estimation, random projections, compressive sensing: Theory and applications in signal processing • Deep neural networks (deep learning): Models, learning algorithms, libraries and ICT applications
2	**Learning objectives / Learning Outcomes** Students are able to interpret and categorize specific engineering problems from the ICT domain in terms of machine learning problems. They are able to reduce such problems to standard machine learning problems and are able to determine suitable solution methods for them. They are able to implement all necessary algorithms from scratch, but they are also familiar with the state-of-the-art libraries in machine learning. They are able to determine the involved computational complexity of a method and choose an appropriate solution algorithms based on application constraints. They are able to apply the acquired methods to other domains, such as data analysis in biomedical engineering, analysis of social network data, etc.
3	**Recommended prerequisite for participation** Good command of Matlab (for instance knowledge from course 18-st-2030 Matlab Grundkurs) and engineering mathematics
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc etit, BSc/MSc iST, MSc iCE, MSc CE

7	**Grade bonus compliant to §25 (2)**
8	**References** • Kevin P. Murphy. Machine Learning – A probabilistic perspective, MIT Press, 2012 • Christopher M. Bishop. Pattern recognition and Machine Learning, Springer, 2006 • Peter Bühlmann und Sara van de Geer. Statistics of high-dimensional data – Methods, theory and applications, Springer, 2011

Courses

Course Nr.	Course name		
18-kp-2110-vl	Machine Learning in Information and Communication Technology (ICT)		
Instructor		**Type**	**SWS**
Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein, Prof. Dr.-Ing. Abdelhak Zoubir, Prof. Dr.-Ing. Marius Pesavento		Lecture	2
Course Nr.	**Course name**		
18-kp-2110-pr	Machine Learning in Information and Communication Technology (ICT) Lab		
Instructor		**Type**	**SWS**
Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein, Prof. Dr.-Ing. Abdelhak Zoubir, Prof. Dr.-Ing. Marius Pesavento		Internship	1
Course Nr.	**Course name**		
18-kp-2110-ue	Machine Learning in Information and Communication Technology (ICT)		
Instructor		**Type**	**SWS**
Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein, Prof. Dr.-Ing. Abdelhak Zoubir, Prof. Dr.-Ing. Marius Pesavento		Practice	1

Module name Matrix Analysis and Computations					
Module Nr. 18-pe-2070	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1	**Content** This graduate course is a foundation class on matrix analysis and computations, which are widely used in many different fields, e.g., machine learning, computer vision, systems and control, signal and image processing, communications, networks, optimization, and many more... Apart from the theory this course will also cover the design of efficient algorithm and it considers many different examples from the aforementioned fields including examples from social media and big data analysis, image processing and medical imaging, communication network optimization, and written text classification. Specific topics: (i) basic matrix concepts, subspace, norms, (ii) linear least squares (iii) eigendecomposition, singular value decomposition, positive semidenite matrices, (iv) linear system of equations, LU decomposition, Cholesky decomposition (v) pseudo-inverse, QR decomposition (vi) advanced tensor decomposition, advanced matrix calculus, compressive sensing, structured matrix factorization
2	**Learning objectives / Learning Outcomes** Students will learn matrix analysis and computations at an advanced or research level.
3	**Recommended prerequisite for participation** Basic knowledge in linear algebra.
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module**
7	**Grade bonus compliant to §25 (2)**
8	**References** 1.Gene H. Golub and Charles F. van Loan, Matrix Computations (Fourth Edition), John Hopkins University Press, 2013. 2.Roger A. Horn and Charles R. Johnson, Matrix Analysis (Second Edition), Cambridge University Press, 2012. 3.Jan R. Magnus and Heinz Neudecker, Matrix Differential Calculus with Applications in Statistics and Econometrics (Third Edition), John Wiley and Sons, New York, 2007. 4.Giuseppe Calaore and Laurent El Ghaoui, Optimization Models, Cambridge University Press, 2014. ECE 712 Course Notes by Prof. Jim Reilly, McMaster University, Canada (friendly notes for engineers) http://www.ece.mcmaster.ca/faculty/reilly/ece712/course_notes.htm

Courses

Course Nr.	**Course name**		
18-pe-2070-vl	Matrix Analysis and Computations		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Lecture	3

	Course Nr.	Course name		
	18-pe-2070-ue	Matrix Analysis and Computations		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Marius Pesavento		Practice	1

Module name					
Robust Signal Processing With Biomedical Applications					
Module Nr. 18-zo-2090	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Dr.-Ing. Michael Muma		

1 Content

1. Robust Signal Processing and Learning
   - Measuring robustness
   - Robust estimation of the mean and the variance
   - Robust regression models
   - Robust filtering
   - Robust location and covariance estimation
   - Robust clustering and classification
   - Robust time-series and spectral analysis

2. Biomedical Applications
   - Body-worn sensing of physiological parameters
   - Electrocardiogram (ECG)
   - Photoplethysmogram (PPG)
   - Eye research
   - Intracranial Pressure (ICP)
   - Algorithms for cardiac activity monitoring

The lecture covers fundamental topics and recent developments in robust signal processing. Unlike classical signal processing, which relies strongly on the normal (Gaussian) distribution, robust methods can tolerate impulsive noise, outliers and artifacts that are frequently encountered in biomedical applications. Robust signal processing and biomedical application lectures alternate. Exercises revise the theory and apply robust signal processing algorithms to real world data.

2 Learning objectives / Learning Outcomes

Students understand the basics of robust signal processing and data science and are able to apply them to a variety of problems. They are familiar with various biomedical applications and know the causes of artifacts, outliers and impulsive noise. They can apply algorithms for robust regression, cluster analysis, classification and spectral analysis.

3 Recommended prerequisite for participation

Fundamental knowledge of statistical signal processing

4 Form of examination

Module Final Examination:
- Module Examination (Technical Examination, Written Examination, Duration: 180 min, Standard Grading System)

5 Grading

Module Final Examination:
- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc Wi-ETiT, MSc iCE, MSc iST

7 Grade bonus compliant to §25 (2)

8 References

A manuscript and lecture slides can be downloaded via Moodle. Further reading

- Zoubir, A. M. and Koivunen, V. and Ollila, E. and Muma, M.: Robust Statistics for Signal Processing. Cambridge University Press, 2018.
- Zoubir, A. M. and Koivunen, V. and Chackchoukh J, and Muma, M. Robust Estimation in Signal Processing: A Tutorial-Style Treatment of Fundamental Concepts. IEEE Signal Proc. Mag. Vol. 29, No. 4, 2012, pp. 61-80.
- Huber, P. J. and Ronchetti, E. M.: Robust Statistics. Wiley Series in Probability and Statistics, 2009.
- Maronna, R. A. and Martin, R. D. and Yohai, V. J.: Robust Statistics: Theory and Methods. Wiley Series in Probability and Statistics, 2006.

Courses

Course Nr.	**Course name**		
18-zo-2090-vl	Robust Signal Processing With Biomedical Applications		
Instructor		**Type**	**SWS**
Dr.-Ing. Michael Muma		Lecture	3

Course Nr.	**Course name**		
18-zo-2090-ue	Robust Signal Processing With Biomedical Applications		
Instructor		**Type**	**SWS**
Dr.-Ing. Michael Muma		Practice	1

Module name Data Science I					
Module Nr. 18-zo-2110	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 90 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Content

The course covers the following topics:

- Python programming basics
- Data science introduction
- Data storage and formats
- Data exploration and visualization
- Statistical methods and inference
  - Descriptive statistics (uni & bivariate)
  - Inferential statistics

- Feature extraction
  - Time Series Data
  - Image data
  - Audio data

- Statistical learning
  - Cross-validation, overfitting, annotation
  - Regression
  - Classification

2 Learning objectives / Learning Outcomes

The course provides a full introduction to data science with an emphasis on hands-on examples. Students will acquire relevant knowledge of the whole data science chain: From storage/acquisition to statistical inference to visualization. It also serves as an introductory course to the Data Science project seminar.

3 Recommended prerequisite for participation

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written/Oral Examination, Duration: 90 min, Standard Grading System)

In general, the examination takes place in form of a written exam (duration: 90 minutes). If up to 15 students register, there will will be an oral examination (duration: 45 min.). The type of examination will be announced within one working week after the end of the examination registration phase.

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written/Oral Examination, Weighting: 100 %)

6 Usability of this module

7 Grade bonus compliant to §25 (2)

Yes

8 References

- Lecture notes and slides can be downloaded here:
  - http://www.spg.tu-darmstadt.de
  - moodle
- Further reading:
  - Wes McKinney: Python for Data Analysis, O'Reilly, 2017
  - Christopher M. Bishop: Pattern Recognition and Machine Learning, 2011
  - James, Witten, Hastie and Tibshirani, Introduction to Statistical Learning, Springer, 2017

Courses

Course Nr.	Course name	Instructor	Type	SWS
18-zo-2110-vl	Data Science I	Dr.-Ing. Christian Debes	Lecture	2
18-zo-2110-ue	Data Science I	Dr.-Ing. Christian Debes	Practice	2

Module name					
Graph signal processing, learning and optimization					
Module Nr. 18-pe-2080	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1 Content

The course covers the following topics:

- Motivation, Applications
- Fundamentals
  - definition of graphs, classes of graphs, properties of graphs, signals defined over graphs
  - Adjecency matrix, Graph Laplacian, Graph shift operator
  - Covariance matrix, conditional dependence, precision matrix
- Graph signal processing
  - Consensus, Diffusion
  - Graph spectral analysis, Graph Fourier Transform
  - Total variational norm, Graph Frequencies
  - Bandlimited graph signals, smoothness
  - Graph filters, Graph sampling theorem
  - Applications
- Network topology inference
  - Link prediction
  - Association network inference
  - Tomographic network topology inference
  - Pearson product-moment correlation
  - Causality, Partial correlation
  - Conditional independence graph
  - Gaussian Markov Random Fields
  - Graphical LASSO, Graphical LASSO with Laplacian constraint
  - Applications
- Graph analysis
  - Subgraph identification
  - Cliques identification
- Optimization over graphs
  - Average consensus, diffusion, exact diffusion
  - Gradient tracking, push-sum algorithm, etc.
  - Applications
- Graph neuronal (convolutional) network

2 Learning objectives / Learning Outcomes

Graph signal processing (i.e., processing of signals defined over graphs) and network analysis form an interdisciplinary research area with many diverse applications. The course provides a systematic introdution to the theory of graph signal processing, graphical network analysis, graph topology learning, optimization over graphs and learning with graph neuronal networks. In this course the students will learn the main concepts, algorithms and application areas that are fundamental in graph signal processing.

3 Recommended prerequisite for participation

Basic knowledge in linear algebra and matrix analysis.

4 Form of examination

	Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Duration: 120 min, Standard Grading System) In general, the examination takes place in form of a written exam (duration: 120 minutes). If up to 20 students register in semesters in which the lecture does not take place, there will will be an oral examination (duration: 20 min.). The type of examination will be announced within one working weeks after the end of the examination registration phase.
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module**
7	**Grade bonus compliant to §25 (2)**
8	**References** • Lecture notes and slides can be downloaded here: – www.nts.tu-darmstadt.de – moodle • Further reading: – Petar M. Djuric, Cédric Richard, Cooperative and Graph Signal Processing, Academic Press, 2018, ISBN 9780128136775.

Courses

Course Nr.	Course name		
18-pe-2080-vl	Graph signal processing, learning and optimization		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Lecture	3
Course Nr.	**Course name**		
18-pe-2080-ue	Graph signal processing, learning and optimization		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Practice	1

Module name Advanced Topics in Statistical Signal Processing					
Module Nr. 18-zo-2040	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Content

This course extends the signal processing fundamentals taught in DSP towards advanced topics that are the subject of current research. It is aimed at those with an interest in signal processing and a desire to extend their knowledge of signal processing theory in preparation for future project work (e.g. Diplomarbeit) and their working careers. This course consists of a series of five lectures followed by a supervised research seminar during two months approximately. The final evaluation includes students seminar presentations and a final exam.

The main topics of the Seminar are:

- Estimation Theory
- Detection Theory
- Robust Estimation Theory
- Seminar projects: e.g. Microphone array beamforming, Geolocation and Tracking, Radar Imaging, Ultrasound Imaging, Acoustic source localization, Number of sources detection.

2 Learning objectives / Learning Outcomes

Students obtain advanced knowledge in signal processing based on the fundamentals taught in DSP and ETiT 4. They will study advanced topics in statistical signal processing that are subject to current research. The acquired skills will be useful for their future research projects and professional careers.

3 Recommended prerequisite for participation

DSP, general interest in signal processing is desirable.

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

MSc ETiT, BSc/MSc iST, MSc iCE, Wi-ETiT

7 Grade bonus compliant to §25 (2)

8 References

- L. L. Scharf, Statistical Signal Processing: Detection, Estimation, and Time Series Analysis (New York: Addison-Wesley Publishing Co., 1990).
- S. M. Kay, Fundamentals of Statistical Signal Processing: Estimation Theory (Book 1), Detection Theory (Book 2).
- R. A. Maronna, D. R. Martin, V. J. Yohai, Robust Statistics: Theory and Methods, 2006.

Courses

	Course Nr.	Course name		
	18-zo-2040-se	Advanced Topics in Statistical Signal Processing		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Abdelhak Zoubir		Seminar	4

Module name Project Seminar Advanced μWave Components & Antennas					
Module Nr. 18-jk-2060	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1	**Content** Groups of 2-3 students per project. Students work out a well defined fundamental or actual research- related problem. The projects will be actualized in each cycle being offered and introduced at the beginning. Each group will be supervised individually. The projects comprises modern antennas for multitudinous applications, electronically-steerable antennas, RFIDs, RF sensors, adaptive tunable components such as matching networks, filter, passive mixer and modulator for next-generation mobile terminals and sensor systems.
2	**Learning objectives / Learning Outcomes** Research-oriented Project Seminar in groups of 2-3 students per project with individual supervision. Students will learn • how to solve scientific hardware-oriented problems • working out concepts • how to design, realize and characterize RF devices • how to use commercial software and characterization tools • to evaluate and discuss their work in the context of the state-of-art in this field • to write a brief scientific report about their work • to present and discus their results at the end of the Project Seminar
3	**Recommended prerequisite for participation** Fundamentals of Microwave Engineering I and Antennas and Adaptive Beamforming
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Duration: 30 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iCE, Wi-ETiT
7	**Grade bonus compliant to §25 (2)**
8	**References** Publications will be hand out to them. Software and characterization tools as well as tools to realize RF devices are available.

Courses

Course Nr.	**Course name**		
18-jk-2060-pj	Project Seminar Advanced μWave Components & Antennas		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Rolf Jakoby, Dr.-Ing. Martin Schüßler		Project Seminar	4

<table>
<tr><td colspan="8">Module name
Project Seminar Wireless Communications</td></tr>
<tr><td colspan="2">Module Nr.
18-kl-2040</td><td>Credit Points
8 CP</td><td>Workload
240 h</td><td>Self study
180 h</td><td>Duration
1</td><td colspan="2">Cycle offered
SoSe</td></tr>
<tr><td colspan="4">Language
English</td><td colspan="4">Module owner
Prof. Dr.-Ing. Anja Klein</td></tr>
<tr><td>1</td><td colspan="7">Content
Solving special Problems concerning mobile communications (problems concerning signal transmission and processing as well as problems concerning the network are possible, topics will be defined out of the current research topics of the lab),
working on the project in teams together (2-3 students)
organizing and structuring of a project
dealing with scientific publications, reading up the theoretical background of the task
practical work on a complex task
scientific presentation of the results (report/presentation)
defending the work in an oral discussion including an audience</td></tr>
<tr><td>2</td><td colspan="7">Learning objectives / Learning Outcomes
After completion of the course, students possess
• the ability to classify and analyze special problems concerning mobile communications,
• the knowledge to plan and organize projects with temporal limitation,
• the capability to setup and test methodologies for analysis and simulation- environments,
• skills to evaluate and present achieved results and achieved conclusions.</td></tr>
<tr><td>3</td><td colspan="7">Recommended prerequisite for participation
Previous knowledge in digital communications, signal processing, mobile radio</td></tr>
<tr><td>4</td><td colspan="7">Form of examination
Module Final Examination:
• Module Examination (Study Achievement, Oral Examination, Duration: 20 min, Standard Grading System)</td></tr>
<tr><td>5</td><td colspan="7">Grading
Module Final Examination:
• Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)</td></tr>
<tr><td>6</td><td colspan="7">Usability of this module
MSc ETiT, MSc Wi-ETiT, MSc CE, MSc iCE, MSc iST, MSc MEC</td></tr>
<tr><td>7</td><td colspan="7">Grade bonus compliant to §25 (2)</td></tr>
<tr><td>8</td><td colspan="7">References
Lecture documentation will be provided and specific literature will be announced during the course.</td></tr>
<tr><td colspan="8">Courses</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Course Nr.
18-kl-2040-pj</td><td colspan="5">Course name
Project Seminar Wireless Communications</td></tr>
<tr><td colspan="5">Instructor
Prof. Dr.-Ing. Anja Klein</td><td>Type
Project Seminar</td><td>SWS
4</td></tr>
</table>

Module name Projekt Seminar Advanced Algorithms for Smart Antenna Systems					
Module Nr. 18-pe-2040	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1	**Content** This project-seminar course introduces the basics of the theory and applications of smart antennas including space-time and multiple-input multiple-output communications, direction-of-arrival estimation and source localization in antenna arrays, and adaptive multiantenna techniques for interference suppression, adaptive transmit and receive beamforming, concensus and defusion algorithms for wireless sensor networks.
2	**Learning objectives / Learning Outcomes** Students will understand theory, algorithms and applications of smart antennas.
3	**Recommended prerequisite for participation** Knowledge of basic communication theory
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Duration: 40 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc Wi-ETiT, MSc iCE
7	**Grade bonus compliant to §25 (2)**
8	**References** 1. Daniel P. Palomar and Yonina C. Eldar, Convex Optimization in Signal Processing and Communications, Cambridge University Press, 2009. 2. Harry L. Van Trees, Optimum Array Processing: Part IV of Detection, Estimation, and Modulation Theory, John Wiley & Sons, 2002. 3. Y. Hua, A.B. Gershman and Q. Cheng (Editors), High-Resolution and Robust Signal Processing, Marcel Dekker, NY, 2004. 4. A.B. Gershman and N.D. Sidiropoulos (Editors), Space-Time Processing for MIMO Communications, Wiley & Sons, 2005.

Courses

Course Nr. 18-pe-2040-pj	**Course name** Projekt Seminar Advanced Algorithms for Smart Antenna Systems		
Instructor Prof. Dr.-Ing. Marius Pesavento, M.Sc. Gerta Kushe		**Type** Project Seminar	**SWS** 4

Module name					
Signal Detection and Parameter Estimation					
Module Nr. 18-zo-2050	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1	**Content** Signal detection and parameter estimation are fundamental signal processing tasks. In fact, they appear in many common engineering operations under a variety of names. In this course, the theory behind detection and estimation will be presented, allowing a better understanding of how (and why) to design "good" detection and estimation schemes. These lectures will cover: Fundamentals Detection Theory Hypothesis Testing Bayesian Tests Ideal Observer Tests Neyman-Pearson Tests Receiver Operating Characteristics Uniformly Most Powerful Tests The Matched Filter Estimation Theory Types of Estimators Maxmimum Likelihood Estimators Sufficiency and the Fisher-Neyman/Factorisation Criterion Unbiasedness and Minimum variance Fisher Information and the CRB Asymptotic properties of the MLE
2	**Learning objectives / Learning Outcomes** Students gain deeper knowledge in signal processing based on the fundamentals taught in DSP and EtiT 4. Thexy will study advanced topics of statistical signal processing in the area of detection and estimation. In a sequence of 4 lectures, the basics and important concepts of detection and estimation theory will be taught. These will be studied in dept by implementation of the methods in MATLAB for practical examples. In sequel, students will perform an independent literature research, i.e. choosing an original work in detection and estimation theory which they will illustrate in a final presentation. This will support the students with the ability to work themselves into a topic based on literature research and to adequately present their knowledge. This is especially expected in the scope of the students' future research projects or in their professional carreer.
3	**Recommended prerequisite for participation** DSP, general interest in signal processing
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT,MSc iST, MSc iCE, Wi-ETiT
7	**Grade bonus compliant to §25 (2)**
8	**References**

- Lecture slides
- Jerry D. Gibson and James L. Melsa. Introduction to Nonparametric Detection with Applications. IEEE Press, 1996.
- S. Kassam. Signal Detection in Non-Gaussian Noise. Springer Verlag, 1988.
- S. Kay. Fundamentals of Statistical Signal Processing: Estimation Theory. Prentice Hall, 1993.
- S. Kay. Fundamentals of Statistical Signal Processing: Detection Theory. Prentice Hall, 1998.
- E. L. Lehmann. Testing Statistical Hypotheses. Springer Verlag, 2nd edition, 1997.
- E. L. Lehmann and George Casella. Theory of Point Estimation. Springer Verlag, 2nd edition, 1999.
- Leon-Garcia. Probability and Random Processes for Electrical Engineering. Addison Wesley, 2nd edition, 1994.
- P. Peebles. Probability, Random Variables, and Random Signal Principles. McGraw-Hill, 3rd edition, 1993.
- H. Vincent Poor. An Introduction to Signal Detection and Estimation. Springer Verlag, 2nd edition, 1994.
- Louis L. Scharf. Statistical Signal Processing: Detection, Estimation, and Time Series Analysis. Pearson Education POD, 2002.
- Harry L. Van Trees. Detection, Estimation, and Modulation Theory, volume I,II,III,IV. John Wiley & Sons, 2003.
- A. M. Zoubir and D. R. Iskander. Bootstrap Techniques for Signal Processing. Cambridge University Press, May 2004.

Courses

Course Nr.	**Course name**		
18-zo-2050-se	Signal Detection and Parameter Estimation		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Abdelhak Zoubir		Seminar	4

Module name Projekt Seminar Procedures for Massive MIMO and 5G					
Module Nr. 18-pe-2050	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1 Content

This project-seminar introduces the basics concepts of the signal processing algorithms and cross-layer procedures for extremely large so-called Massive MIMO systems and mobile communication networks of the 5th generation (5G).

In Massive MIMO systems the number of base transmit and receive antennas at the base station are scaled up, as compared to usual MIMO systems, by several orders of magnitude.In this seminar we investigate advanced signal processing algorithms which allow to exploit the advantages of Massive MIMO in an optimum way (which are high data rate, high reliability, favorable propagation characteristics), to cope with the enormous date volume (linear signal processing) and to master the challenges (pilot contamination, low-cost hardware). Massive MIMO is an integral part of the emerginjg 5G mobile communication networks. In the course of the seminar the fundamental concepts and challenges of 5G networks will be discussed. It includes concepts as Small Cells, Cloud RAN, Network Virtualization, Network slicing, Machine-to-Machine communication, Millimeter Wave Transmission, Flexible Waveforms, etc.

2 Learning objectives / Learning Outcomes

Students will learn the fundamental concepts, procedures, theories, algorithms and applications of Massive MIMO systems and 5 G mobile communication networks by the latest scientific publications.

3 Recommended prerequisite for participation

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Duration: 40 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc Wi-ETiT, MSc iCE

7 Grade bonus compliant to §25 (2)

8 References

- http://www.commsys.isy.liu.se/vlm/icc_tutorial_P1.pdf
- http://www.commsys.isy.liu.se/vlm/icc_tutorial_P2.pdf
- http://www.massivemimo.eu/
- A. Chockalingam and B. Sundar Rajan. *Large MIMO Systems*, Cambridge University Press. Cambridge, 2015
- NGMN Alliance (2015) 5G White Paper https://www.ngmn.org/uploads/media/NGMN_5G_White_Paper_V1_0.

Courses

Course Nr.	**Course name**		
18-pe-2050-pj	Projekt Seminar Procedures for Massive MIMO and 5G		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Project Seminar	4

Module name					
Robust and Biomedical Signal Processing					
Module Nr. 18-zo-2100	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Content

A series of 3 lectures provides the necessary background on robust signal processing and machine learning:

- Background on robust signal processing
- Robust regression and robust filters for artifact cancellation
- Robust location and covariance estimation and classification

They are followed by two lectures on selected biomedical applications, such as:

- Body-worn sensing of physiological parameters
- Optical heart rate sensing (PPG)
- Signal processing for the electrocardiogram (ECG)
- Biomedical image processing

Students then work in groups to apply robust signal processing algorithms to real-world biomedical data. Depending on the application, the data is either recorded by the students, or provided to them. The group results are presented during a 20-minute presentation. The final assessment is based on the presentation and an oral examination.

2 Learning objectives / Learning Outcomes

3 Recommended prerequisite for participation

Fundamental knowledge of statistical signal processing

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc Wi-ETiT, MSc iCE, MSc iST

7 Grade bonus compliant to §25 (2)

8 References

- Slides can be downloaded via Moodle.

Further reading:

- Zoubir, A. M. and Koivunen, V. and Ollila, E. and Muma, M.: Robust Statistics for Signal Processing. Cambridge University Press, 2018.
- Zoubir, A. M. and Koivunen, V. and Chackchoukh J, and Muma, M. Robust Estimation in Signal Processing: A Tutorial-Style Treatment of Fundamental Concepts. IEEE Signal Proc. Mag. Vol. 29, No. 4, 2012, pp. 61-80.
- Huber, P. J. and Ronchetti, E. M.: Robust Statistics. Wiley Series in Probability and Statistics, 2009.
- Maronna, R. A. and Martin, R. D. and Yohai, V. J.: Robust Statistics: Theory and Methods. Wiley Series in Probability and Statistics, 2006.

Courses				
	Course Nr. 18-zo-2100-se	**Course name** Robust and Biomedical Signal Processing		
	Instructor Dr.-Ing. Michael Muma		**Type** Seminar	**SWS** 4

Module name					
International Summer School 'Microwaves and Lightwaves'					
Module Nr. 18-pr-2020	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 90 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr. rer. nat. Sascha Preu		

1 Content

This lecture covers the fundamentals and the latest deveolpments of microwave electronics, THz technology, and optical communication systems with particular focus on the physical concepts involved.

2 Learning objectives / Learning Outcomes

Students understand

- the background of microwave enginering, THz engineering, and optical communications and
- of related electronics, and
- the influence of the relevant properties of materials and of waveguides on signal processing.

They gain inside into the latest developments in these fields.

3 Recommended prerequisite for participation

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)

6 Usability of this module

BSc ETiT, MSc ETiT

7 Grade bonus compliant to §25 (2)

8 References

A script (English) will be distributed and English slides can be downloaded.

Courses

Course Nr.	Course name		
18-pr-2020-se	International Summer School "Microwaves and Lightwaves"		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Sascha Preu, Prof. Dr.-Ing. Rolf Jakoby, Prof. (em.) Dr.-Ing. Dr.h.c. Hans Ludwig Hartnagel, Prof. Dr.-Ing. Franko Küppers		Seminar	2

Module name Introduction to Scientific Computing with Python					
Module Nr. 18-st-2070	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 90 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German			**Module owner** Prof. Dr. rer. nat. Florian Steinke		

1	**Content** Scientific computing is introduced via six case studies. Exemplary engineering problems that are know from basic engineering courses are solved on a computer using fundamental methods from numerical mathematics. Opportunities and limitations of this approach are highlighted. The required material on numerical mathematics is taught via preparatory scripts for each case study. During the practical exercises the methods are implemented in the current computing environment Python under the guidance of suitable teaching personnel. The case studies cover the following numerical topics: • Formulation and solution of systems of linear equations, sparse methods • Integration of ordinary differential equations (ODE) and their analysis based on eigenvalues • Mathematical optimization and automated differentiation • Linear regression and approximation, first Machine Learning algorithms • Discretization of simple partial differential equations (PDE)
2	**Learning objectives / Learning Outcomes** Students have a first experience of solving engineering problems on a computer. They know how to apply fundamental technologies of numerical mathematics and are familiar with an algorithmic approach to problem solving. They know opportunities and limitations of computer-aided solution methods.
3	**Recommended prerequisite for participation** Etit 1 & 2, Mathe for etit 1-3
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Written/Oral Examination, Standard Grading System) The type of examination will be announced in the first lecture. Possible types could be: Creating reports and descriptions of experiments as well as presentations of experiments and results.
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module** Etit B.A./M.Sc. with all options, as well as CE, ICE, IST
7	**Grade bonus compliant to §25 (2)**
8	**References**

Courses

Course Nr.	**Course name**		
18-st-2070-pr	Introduction to Scientific Computing with Python		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Florian Steinke, Prof. Dr. rer. nat. Sebastian Schöps, Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Herbert De Gersem, Prof. Dr. rer. nat. Markus Meinert		Internship	2

Module name Data Science II					
Module Nr. 18-zo-2120	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Content

The course covers the following topics:

- Data Science Advanced Methods
- Data Management + Big data frameworks
- Statistical Learning
  - Recommender Systems
  - Deep Learning
  - Unsupervised Learning
  - Text data analysis
- Final application project. Flexibility to choose from list of projects or come up with own project. Examples:
  - Sound classification
  - Heart rate analysis
  - Activity recognition with acceleration data
  - Hyperspectral data
  - Image classification
  - Health survey

2 Learning objectives / Learning Outcomes

This seminar provides an advanced understanding of data science with an emphasis on hands-on projects. Students will get to know latest data science technologies – from big data to advanced machine learning and apply them in a real-world project.

3 Recommended prerequisite for participation

Data Science I (Lecture)

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Written/Oral Examination, Duration: 90 min, Standard Grading System)

In general, the examination takes place in form of a written exam (duration: 90 minutes). If up to 14 students register, there will will be an oral examination (duration: 45 min.). The type of examination will be announced in the first lecture. Possible types include a project presentation, etc.

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Written/Oral Examination, Weighting: 100 %)

6 Usability of this module

7 Grade bonus compliant to §25 (2)

8 References

Lecture notes and slides can be downloaded here:

- http://www.spg.tu-darmstadt.de
- Moodle platform

Further reading:

- Wes McKinney: Python for Data Analysis, O'Reilly, 2017
- Christopher M. Bishop: Pattern Recognition and Machine Learning, 2011
- James, Witten, Hastie and Tibshirani, Introduction to Statistical Learning, Springer, 2017

Courses

Course Nr.	**Course name**		
18-zo-2120-se	Data Science II		
Instructor		**Type**	**SWS**
Dr.-Ing. Christian Debes		Seminar	4